PAN-PACIFIC ENTOMOLOGIST
63(1), 1987, pp. 75–91

Diversity, Seasonality, and Annual Variability of Caddisfly (Trichoptera) Adults from Two Streams in the California Coast Range

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Abstract.—Faunal composition and fluctuations in abundance of Trichoptera adults were analyzed from three years of pan trap collections (1979–1981) made during the dry season (April–October) at two streams (Big Sulphur Creek, Sonoma County; Big Canyon Creek, Lake County) located 11 km apart in the California Coast Range. At least 57 species in 15 families were identified among the 2003 individuals collected; 24 species were common to both sites. The length of the flight period of these adults, on average, was significantly longer than that observed at four temperate sites in eastern North America. Most probably, this is related to the warmer temperature regime associated with the Mediterranean climate of the California Coast Range. When years with varying amounts of precipitation were compared, the annual variability of Coast Range Trichoptera (as measured by year-to-year changes in population abundances) was found to be similar to annual variability observed for other temperate caddisfly faunas. When precipitation amounts were similar, year-to-year differences in caddisfly abundance were reduced.

Introduction

Environments that have stable climatic characteristics have been assumed to exhibit greater faunal and floral diversity (Klopfer, 1959). As a result, tropical areas have been assumed to contain faunas that are less variable temporally than their temperate counterparts (MacArthur, 1972). Wolda (1977, 1978, 1980a, b) and Wolda and Fisk (1981) examined the temporal variability of insect faunas from (mostly terrestrial) habitats worldwide and concluded that tropical insects are often less seasonal than temperate insects, but they also observed that tropical insect populations are not generally more stable on a year-to-year basis (i.e., climatic stability is not reflected in the annual variability of the insect populations). Temperate/tropical comparisons of seasonality and annual variability for aquatic insects are more difficult because most research has been done in areas with continental temperate climates (hot summers, cold winters) and over relatively short terms ($\leq$ 2 years). McElravy et al. (1981, 1982) compared the diversity and temporal variability of an adult caddisfly fauna from a climatically stable "non-seasonal" tropical environment in Panama with several faunas from continental temperate climates in North America and Europe. They found that tropical caddisflies exhibited higher diversity and have longer flight periods than adults of most temperate species, but that these caddisflies did not show an increase in the stability of their populations on a year-to-year basis.

Within the temperate-zone areas of the world there are regions with climatic differences that are analogous to those that occur between the temperate and tropical zones. For example, the streams of the California Coast Range are not tropical, but they are located in a region with a Mediterranean-type climate (i.e., hot, dry summers and mild, wet winters). Subfreezing temperatures are uncommon as a result of maritime influences, and insect faunas in these areas are subject to less seasonal temperature variation than is found in most other temperate-zone sites. Temperature, along with photoperiod, is known to be an important factor in determining several life history features of aquatic insects (e.g., Hynes, 1970; Butler, 1984; Sweeney, 1984).

Does the diversity and temporal variability of caddisflies from temperate-zone streams in regions with Mediterranean climates differ from those in more typical temperate systems (i.e., hot summers, cold winters)? This paper presents the results of a three-year study of Trichoptera adults from two nearby streams in the California Coast Range, and compares the diversity and temporal variability of this fauna with that of other temperate-zone caddisfly communities.

Study Area

Big Sulphur Creek, Sonoma County, California, is a third-order stream that flows northwesterly through The Geysers Known Geothermal Resources Area (KGRA). The stream traverses a steep-sided valley characterized by an unstable terrain (Brown and Jackson, 1974; Neilson, 1975). In this region, more than 95% of the annual precipitation occurs during the rainy season (late September–early May). Following cessation of rains in the spring, streamflows gradually recede, reaching a minimum level by early September. Extensive blooms of the green alga *Cladophora glomerata* (L.) Kutzing can occur within the stream over the summer. Collections of caddisfly adults were made near the confluence of Big Sulphur Creek and a major tributary, Little Geysers Creek (38° 46′N, 122° 45′ W, elevation 680m, gradient 47m/km).

Big Canyon Creek is located in a separate drainage basin approximately 11 km northeast of Big Sulphur Creek in Lake County, California. As at Big Sulphur Creek, most precipitation and maximum discharge occurs from late September to early May. Samples were collected near the headwaters of Big Canyon Creek (38° 51′ N, 122° 41′ W, elevation 570m, gradient 61m/km). At this location, the watershed is covered with a mixed hardwood-conifer forest, which provides dense shading for a large portion of the stream.

Although Big Sulphur Creek and Big Canyon Creek are both within The Geysers KGRA and are subject to similar climatic influences, some differences exist between the two stream systems. First, the liquid-dominated, subsurface, geothermal reservoir in the Big Canyon Creek watershed produces alkaline conditions in the overlying streams; in contrast acidic conditions predominate at Big Sulphur Creek where the geothermal reservoir consists of dry steam (McColl et al., 1978). Second, the presence of numerous springs in the upper reaches of the Big Canyon Creek watershed (and near the study site) reduce seasonal variation in discharge by maintaining higher summer streamflows than in Big Sulphur Creek. Third, much of the substrate at Big Canyon Creek consists of large particles that are "cemented" in place. Compared to the loose gravel-boulder substrate at Big Sulphur Creek, the compacted substrate of Big Canyon Creek is less likely to be displaced during the spates that occur in both watersheds during the wet season; however, this substrate provides less interstitial habitat. Finally, the riparian vegetation at the Big Canyon Creek study site is largely deciduous and quite dense, forming a canopy that provides shading during most of the day. In contrast, the canopy at Big Sulphur Creek is intermittent and the stream is only partially shaded, particularly during the middle of the day. The increased shading, lack of surface geothermal inputs, and presence of numerous springs produce a temperature regime at Big Canyon Creek that is more constant on a seasonal basis than the temperature regime of Big Sulphur Creek. Further descriptions of these streams are provided by Lamberti (1983), Lamberti and Resh (1983), McColl et al. (1978), and McMillan (1985).

Methods

Rainfall.—During most of the period covered by this study daily precipitation data for The Geysers, California, were available from National Oceanic and Atmospheric Administration records (NOAA, Hourly Precipitation Data, California, 1979–1981). Estimates of rainfall for periods with missing data were calculated by the normal-ratio method (Gilman, 1964) using records from surrounding stations.

Collection Methods.—Caddisfly adults were collected using pan traps, which are 28 × 40 cm aluminum pans supported 20–30 cm above the stream surface by a metal frame. The pans are filled with a 50–50 mixture of ethylene glycol and water, and capture and preserve adult insects for periods up to one month (see Resh et al. [1984a, b] for pictures of pan traps and a further description of their use). Although fewer adult insects are collected with pan traps than with traditional attractive traps (such as light traps), we have found that these traps are generally nonselective and that samples obtained provide an accurate, relative estimate of adult insect abundance. Jones and Resh (unpublished data) compared pan trap and Malaise trap captures in a Montana stream; with one exception, pan traps collected all species that had >1 individual in the Malaise trap collections.

At Big Sulphur Creek, four pan traps were placed streamside and continuous collections were made from the end of the rainy season (mid April–early May) until the end of the summer dry season (September) in 1979 and 1981, and until the end of October during 1980. At Big Canyon Creek, four pan traps were used from July until the end of August in 1979, and two to four pan traps were operated from early May until late October in 1980 and until late September in 1981. Pan traps were usually emptied bi-weekly by draining through a 250 μm sieve. Caddisflies were separated from other insects, collected, transferred to alcohol, and identified.

Data Analysis.—Seasonal Range (SR) (Wolda, 1979) is a statistic that measures in weeks the length of the adult flight season of a population, correcting for sample size (SR can be calculated for samples $N \geq 6$ in a given year, Wolda, 1979). Higher values of SR indicate less seasonality for a species (i.e., the adults have longer flight periods during the year). Seasonal Range was calculated for those species in which six or more individuals were collected in a given year (SR was not calculated for Big Canyon Creek species during 1979 because of the short collecting season). In order to compare the seasonality of the fauna at each site with other temperate sites, the SR values for the populations at a given site are arranged in a frequency distribution and differences between sites are analyzed with χ^2 tests.

Year-to-year differences in Seasonal Range values were examined for species in which SR values were available for two or more years. The Annual Variability statistic (AV) of Wolda (1978) provides a measure of the stability of the community in terms of the variability of its constituent populations. This parameter was calculated for the caddisflies at Big Sulphur Creek for the years 1979–1980, 1980–1981, and 1979–1981, and at Big Canyon Creek for 1980–1981; the AV statistic was not calculated for other years due to low numbers of captures. Species for which ≥ 10 individuals were collected in the two years that were being compared were included in the analysis. To make years comparable, data from October 1980 and April 1981 were omitted from Big Sulphur Creek samples, whereas the number of captures at Big Canyon Creek in 1981 was doubled because only two pans were operated (cf. four pans in 1980). The values obtained for both sites were compared with previously reported values of this statistic for temperate and tropical caddisfly communities.

Results and Discussion

Rainfall.—Precipitation data for the rainy season (September–May) at The Geysers indicates a 25-yr. mean ($\pm$SD) of 145 $\pm$38.3 cm yr^{-1}. Total precipitation during the 1979–1980 rainy season (155.1 cm) was near this average. However, the 1978–1979 and 1980–1981 totals were below average (98.4 cm and 90.5 cm, respectively); hence the 1979 and 1981 collections were made during "dry" years.

The Fauna.—During the three-year sampling period 1979–1981 at Big Sulphur Creek, 1039 Trichoptera adults were collected. Although females could not be associated with males for 183 (18%) of these adults, the remaining 856 specimens represent 39 species in 14 families (Table 1). At least 10 of the species (26%) appear to be undescribed (D. Denning, pers. comm.). Since some of the unassociated females are probably not represented by males in the 39-species count, the actual number of species collected is most likely higher.

At Big Canyon Creek, a total of 964 adult Trichoptera was collected during 1979–1981, including 317 unassociated females (33%). The remaining 647 individuals represented 42 species in 15 families (Table 2). At least seven of these species (17%) appear to be undescribed (D. Denning, pers. comm.). A total of 24 species was common to both streams, and at least 57 species were collected from these two sites.

The Trichoptera diversity of Big Sulphur Creek and Big Canyon Creek may be compared with other sites by examining the relationship between the number of species and the number of individuals collected (i.e., the species-abundance curve). These two California sites are near the center of the diversity-abundance distributions for temperate-zone sites in North America and Europe examined by McElravy et al. (1981) and, in terms of diversity, they represent typical temperate caddisfly communities. The proportion of undescribed species (17–26%), however, is much higher than usual (cf. Resh et al. [1975] for a Kentucky stream, Morse et al. [1980] for a South Carolina stream).

Seasonal Occurrence.—The seasonal occurrence of the caddisfly adults at Big Sulphur Creek that composed $\geq 1\%$ of the total number collected from 1979 to 1981 is presented in Fig. 1. Although year-to-year variation is apparent for most of these species, some general patterns can be observed. Most species have adults emerging and active over a fairly long time period in at least one of the years. Only two species, *Rhyacophila angelita* Banks and *Amiocentrus aspilus* (Ross) have short flight periods

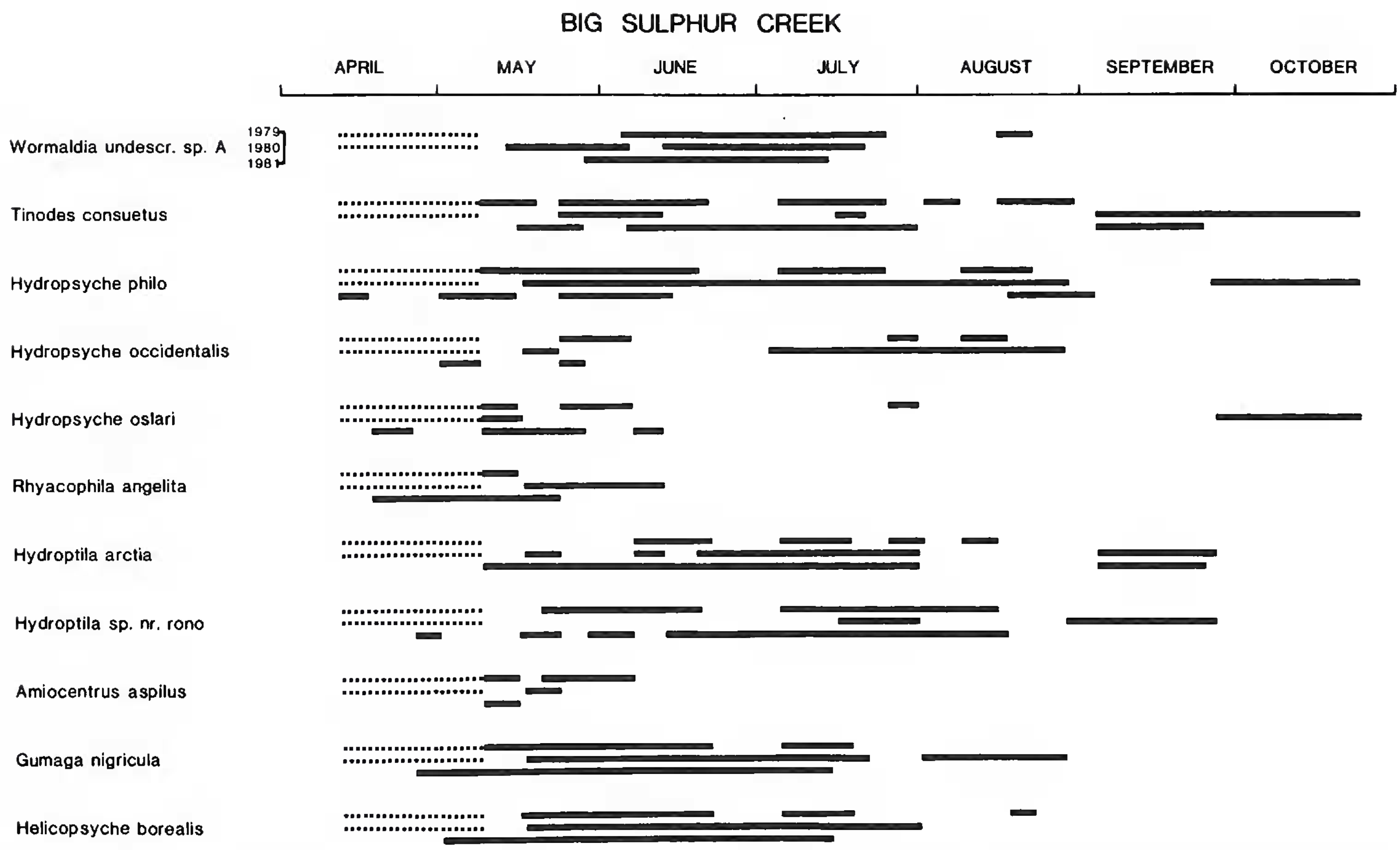

Figure 1. Seasonal occurrence of 11 numerically dominant (⩾ 1% of total 1979–1981) species of Trichoptera collected at Big Sulphur Creek 1979–1981. Values of Seasonal Range (SR) calculated according to Wolda (1979). Dotted lines indicate periods when pan traps were not operated, and for which flight information is not available.

in the spring. The patterns of seasonal occurrence of the 13 species of Trichoptera adults that composed ⩾ 1% of the total collected from 1979–1981 at Big Canyon Creek (Fig. 2) were similar to those observed for the Big Sulphur Creek fauna. Only the Rhyacophilidae (except for *Rhyacophila vao* Milne) and *Amiocentrus aspilus* have short flight periods in the spring.

The seasonal occurrence of the Trichoptera faunas at the two northern California sites was compared with other temperate-zone sites by examining the frequency distributions of the SR statistic between two sites using χ^2 tests. When the distribution of SR for the Big Sulphur Creek fauna (Fig. 3a) is compared with the four temperate sites in eastern North America described in McElravy et al. (1982), the fauna at Big Sulphur Creek is significantly less seasonal in all cases ($p < 0.05$, Table 3); that is, caddisfly adults at Big Sulphur Creek have longer flight periods than the other sites. When a similar comparison is made for the Big Canyon Creek fauna (Fig. 3b), all sites except Mahoning River, Ohio, St. #3, were also significantly less seasonal ($p < 0.05$, Table 3).

These California sites are in an area that is climatically different from the other sites. Most obviously, Big Sulphur Creek and Big Canyon Creek have higher mean air temperatures than the other sites during late fall to early spring (Table 3). As a result, these California streams are not subjected to long periods of near-freezing or subfreezing conditions over the winter, which occur at the other sites that are, at least in respect to temperature, located in a much more severe climate. We assume that these higher temperatures permit longer flight periods for the adult caddisflies by

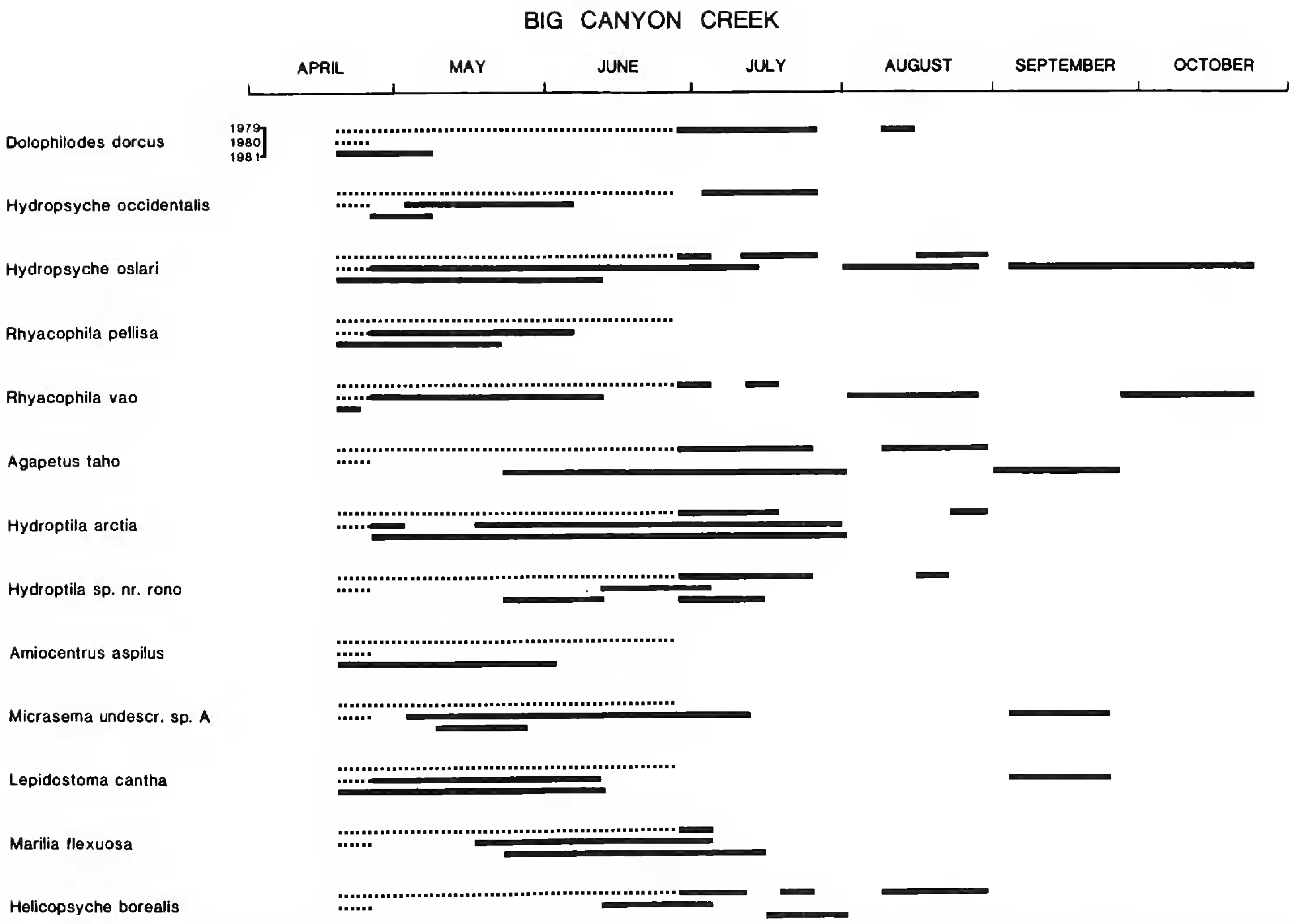

Figure 2. Seasonal occurrence of 13 numerically dominant (≥ 1% of total 1979–1981) species of Trichoptera collected at Big Canyon Creek 1979–1981. Values of Seasonal Range (SR) calculated according to Wolda (1979). Dotted lines indicate periods when pan traps were not operated, and for which flight information is not available.

providing longer periods of favorable weather conditions during early spring and late autumn.

Annual Variability.—At Big Sulphur Creek, the number of taxa varied little over the three years of this study (Table 1). However, the total numbers of individuals varied greatly. For example, the relative abundance of *Helicopsyche borealis* (Hagen), which as larvae are important grazers in this stream (Lamberti and Resh, 1983), and *Hydropsyche spp.* was fairly constant over 1979–1980, but was reduced in 1981 (Table 1). *Gumaga nigricula* (McLachlan), another numerically dominant macroinvertebrate in Big Sulphur Creek (Resh et al., 1981), was less abundant during 1980 than in 1979 or 1981. The 1980 decrease in *G. nigricula* may be related to the higher rainfall totals and increased substrate disturbance the previous winter, which has been shown to adversely affect *G. nigricula* densities (Resh et al., 1981).

Further evidence that substrate disturbance resulting from high winter discharge events can reduce caddisfly densities was obtained when Big Sulphur Creek pan trap collections were made in 1986. The 1985–1986 rainy season included two 50-year floods, both occurring in February, that resulted in considerable rearrangement of stream bed materials, including displacement of large boulders and logs. Only 10 *G. nigricula* adults were collected during 1986, one-half of the 1980 total and less than one-sixth of the numbers of *G. nigricula* collected in 1979 or 1981. A similar trend was observed for total numbers of individuals (89 in 1986; cf. 501 in 1979, 252 in 1980,

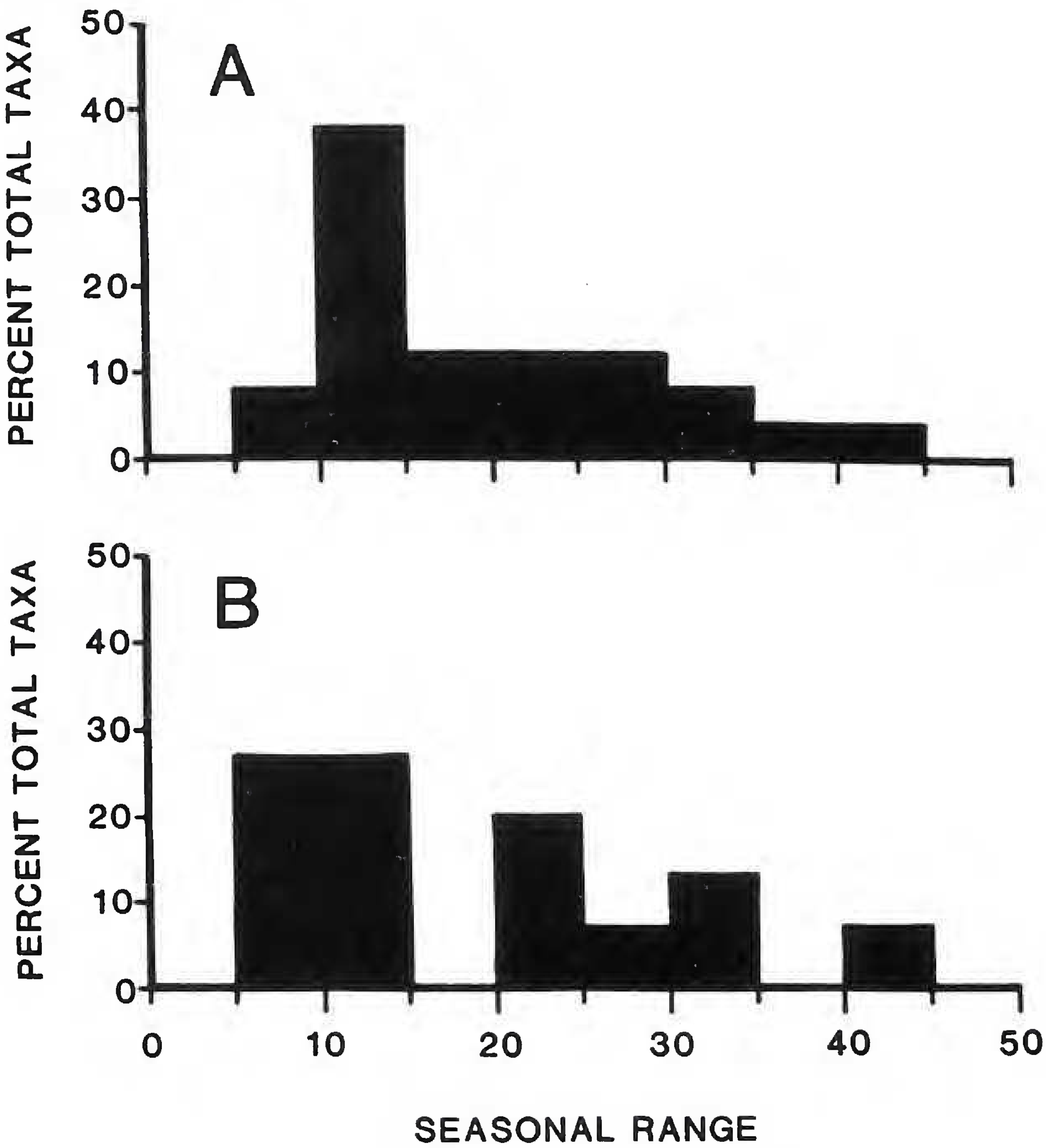

Figure 3. Histograms showing distribution of Seasonal Range (SR) as percentages. Values along abcissa from left to right indicate decreasing seasonality. Trichoptera from A. Big Sulphur Creek (N = 24); B. Big Canyon Creek (N = 15).

and 286 in 1981) as well as number of taxa (14 in 1986; cf. 23 in 1979, 25 in 1980, and 26 in 1981).

At Big Canyon Creek, the number of taxa collected was similar during the two years for which sampling was complete (1980 and 1981) (Table 2). However, the total number of individuals collected decreased from 1980 to 1981. Over this period, the relative abundance of the Lepidostomatidae increased, while that of the Brachycentridae declined. Little change in abundance of Rhyacophilidae was observed (Table 2).

Year-to-year changes in the seasonality of the Trichoptera fauna at Big Sulphur Creek and Big Canyon Creek can be examined with between-year plots of SR for those species with $N \geq 6$ in two or more years. Since SR is corrected for sample size, this procedure allows data, such as presented in Figs. 1 and 2, to be compared. In both 1979–1980 and 1980–1981, the numerically dominant caddisfly species at Big Sulphur Creek did not exhibit similar seasonality patterns over the two years (Fig. 4a,b). This may be related to variation in abiotic and/or biotic factors caused by differences in hydrologic regimes between the two relatively dry years (1979, 1981)

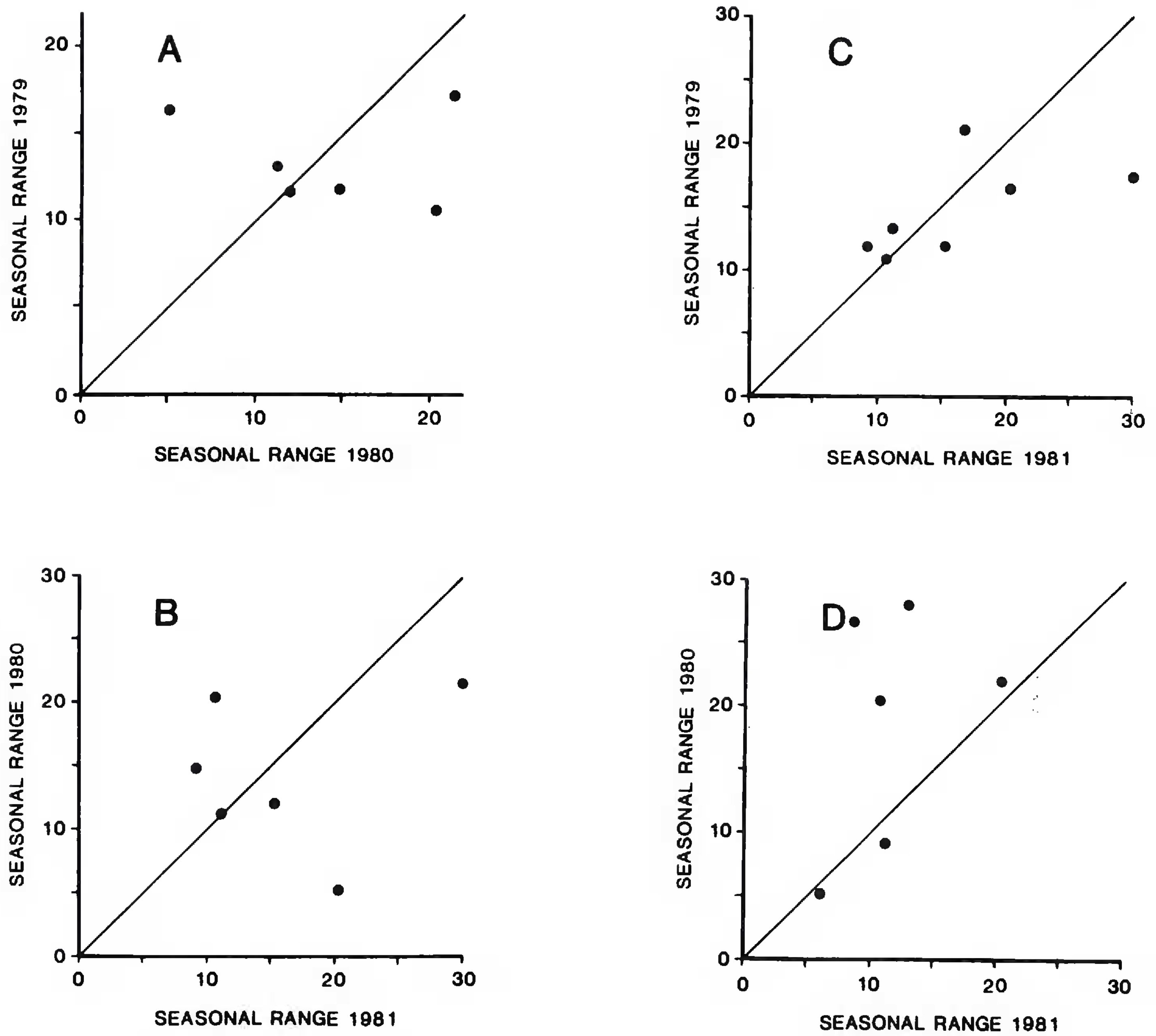

Figure 4. Between-year comparison of seasonal occurrence of Trichoptera adults (measured by SR) at two sites in the central California Coast Range. A. Big Sulphur Creek 1979–1980; B. Big Sulphur Creek 1980–1981; C. Big Sulphur Creek 1979–1981; D. Big Canyon Creek 1980–1981.

and a wetter year (1980). When the two dry years are compared (Fig. 4c), less year-to-year variability in the length of the species' active seasons is evident. Mean wet season stream temperature was probably less important than precipitation in producing this pattern; temperature did not vary between 1979–1980 (October–April mean temperature = 11.4° C) and 1980–1981 (October–April mean temperature = 11.3°) and was lower during 1978–1979 (October–April mean temperature = 9.6°). At Big Canyon Creek (Fig. 4d), a comparison of SR values for 1980–1981 also showed considerable variation for three of the six species examined; these three species had considerably longer active seasons in 1980 than in the relatively dry year of 1981.

Year-to-year variability of the entire fauna at a particular site can be assessed using the Annual Variability statistic (AV) (Wolda, 1978), which takes into account changes in total numbers of each species over the years of comparison. When this statistic is calculated for Big Sulphur Creek (Table 4), the pattern of faunal variation is similar to that seen above when the SR values were plotted, i.e., less variation occurs when the two drier years (1979 and 1981) are compared than when a dry and a

Table 1. Species present, number of individuals collected, and abundance as percent of individuals collected in each year, from Big Sulphur Creek, 1979–1981.

	1979		1980		1981	
	No.	Percent of total	No.	Percent of total	No.	Percent of total
Philopotamidae						
Chimarra undescr. sp. A	2	0.3	0	0.0	2	0.7
Wormaldia undescr. sp. A	44	8.8	12	4.7	21	7.3
Psychomyiidae						
Tinodes consuetus McL.	24	4.8	10	3.9	10	3.5
Tinodes siskiyou Denning	0	0.0	2	0.8	0	0.0
Polycentropodidae						
Polycentropus halidus Milne	0	0.0	1	0.4	0	0.0
Unassociated *Polycentropus* Females:						
Polycentropus sp. #1	3	0.6	0	0.0	0	0.0
Polycentropus sp. #2	1	0.2	0	0.0	0	0.0
Hydropsychidae						
Cheumatopsyche mickeli Denning	3	0.6	5	2.0	0	0.0
Homoplectra oaklandensis (Ling)	1	0.2	0	0.0	0	0.0
Hydropsyche californica Banks	0	0.0	2	0.8	0	0.0
Hydropsyche philo Ross	51	10.2	25	9.8	14	4.9
Hydropsyche occidentalis Banks	5	1.0	7	2.7	2	0.7
Hydropsyche oslari Banks	4	0.8	2	0.8	7	2.4
Hydropsyche sp. A	1	0.2	0	0.0	1	0.3
Parapsyche almota Ross	1	0.2	0	0.0	3	1.0
Rhyacophilidae						
Rhyacophila angelita Banks	1	0.2	3	1.2	12	4.2
Rhyacophila vedra Milne	0	0.0	0	0.0	1	0.3
Rhyacophila vocala Milne	1	0.2	2	0.8	4	1.4
Rhyacophila undescr. sp. A	1	0.2	0	0.0	2	0.7
Rhyacophila undescr. sp. B	0	0.0	1	0.4	1	0.3
Rhyacophila undescr. sp. C	0	0.0	1	0.4	0	0.0
Unassociated *Rhyacophila* Females:						
Rhyacophila sp. #1	1	0.2	2	0.8	4	1.4
Rhyacophila sp. #2	0	0.0	3	1.2	16	5.6
Rhyacophila sp. #3	0	0.0	0	0.0	1	0.3
Rhyacophila sp. #4	0	0.0	0	0.0	1	0.3
Glossosomatidae						
Unassociated *Agapetus* Female:						
Agapetus sp. #1	0	0.0	0	0.0	1	0.3

Table 1. *continued*

	1979 No.	1979 Percent of total	1980 No.	1980 Percent of total	1981 No.	1981 Percent of total
Glossosoma califica Denning	1	0.2	0	0.0	0	0.0
Glossosoma oregonense Ling	0	0.0	0	0.0	1	0.3
Unassociated *Glossosoma* Females:						
Glossosoma sp. #1	0	0.0	2	0.8	0	0.0
Glossosoma sp. #2	0	0.0	0	0.0	3	1.0
Hydroptilidae						
Hydroptila arctia Ross	31	6.2	47	18.7	22	7.7
Hydroptila sp. A nr. *rono* Ross	18	3.6	9	3.5	10	3.5
Unassociated *Hydroptila* Females:						
Hydroptila sp. #1	39	7.8	12	4.7	8	2.8
Hydroptila sp. #2	0	0.0	1	0.4	4	1.4
Ithytrichia sp. A	0	0.0	1	0.4	0	0.0
Neotrichia sp. A	1	0.2	0	0.0	0	0.0
Neotrichia undescr. sp. A	0	0.0	1	0.4	0	0.0
Unassociated *Neotrichia* Female:						
Neotrichia sp. #1	11	2.2	2	0.8	0	0.0
Ochrotrichia undescr. sp. B	0	0.0	0	0.0	1	0.3
Ochrotrichia undescr. sp. C	0	0.0	0	0.0	1	0.3
Ochrotrichia undescr. sp. D	0	0.0	0	0.0	2	0.7
Ochrotrichia undescr. sp. E	1	0.2	0	0.0	1	0.3
Unassociated *Ochrotrichia* Female:						
Ochrotrichia sp. #1	4	0.8	2	0.8	1	0.3
Oxyethira sp. A	0	0.0	5	2.0	0	0.0
Unassociated Hydroptilidae Females:						
Hydroptilidae sp. #1	0	0.0	3	1.2	0	0.0
Brachycentridae						
Amiocentrus aspilus (Ross)	4	0.8	3	1.2	2	0.7
Unassociated *Amiocentrus* Females:						
Amiocentrus sp. #1	2	0.3	0	0.0	0	0.0
Amiocentrus sp. #2	5	1.0	3	1.2	14	4.9

Table 1. *continued*

	1979 No.	1979 Percent of total	1980 No.	1980 Percent of total	1981 No.	1981 Percent of total
Lepidostomatidae						
Lepidostoma strophis Ross	7	1.4	0	0.0	1	0.3
Unassociated *Lepidostoma* Females:						
Lepidostoma sp. #1	15	3.0	3	1.2	2	0.7
Lepidostoma sp. #2	0	0.0	1	0.4	0	0.0
Sericostomatidae						
Gumaga nigricula (McL.)	78	15.6	20	7.9	62	21.7
Odontoceridae						
Marilia flexuosa Ulmer	0	0.0	1	0.4	0	0.0
Unassociated *Marilia* Females:						
Marilia sp. #1	0	0.0	1	0.4	0	0.0
Marilia sp. #2	4	0.8	0	0.0	0	0.0
Unassociated Odontoceridae Female:						
Odontoceridae sp. #1	0	0.0	0	0.0	1	0.3
Helicopsychidae						
Helicopsyche borealis (Hagen)	126	25.1	51	20.2	42	14.7
Calamoceratidae						
Heteroplectron californicum McL.	0	0.0	1	0.4	2	0.7
Leptoceridae						
Mystacides alafimbriata Hill-Griffin	0	0.0	2	0.8	1	0.3
Ylodes frontalis (Banks)	6	1.2	2	0.8	0	0.0
Unassociated *Ylodes* Females:						
Ylodes sp. #1	0	0.0	0	0.0	1	0.3
Ylodes sp. #2	4	0.8	1	0.4	1	0.3
Total N	501		252		286	
Total No. Taxa (Excluding Unassociated Females)	23		25		26	
No. Unassociated Females	89		36		58	

Table 2. Species present, number of individuals collected, and abundance as percent of individuals collected in each year, from Big Canyon Creek, 1979–1981.

	1979 No.	1979 Percent of total	1980 No.	1980 Percent of total	1981 No.	1981 Percent of total
Philopotamidae						
Dolophilodes dorcus (Ross)	24	16.7	0	0.0	2	0.6
Wormaldia cruzensis (Ling)	0	0.0	1	0.2	0	0.0
Wormaldia undescr. sp. A	0	0.0	2	0.4	0	0.0
Psychomyiidae						
Nyctiophylax sp. A	0	0.0	0	0.0	1	0.3
Tinodes siskiyou Denning	1	0.7	1	0.2	0	0.0
Unassociated *Tinodes* Female:						
Tinodes sp. #1	0	0.0	2	0.4	0	0.0
Polycentropodidae						
Polycentropus halidus Milne	0	0.0	2	0.4	1	0.3
Unassociated *Polycentropus* Female:						
Polycentropus sp. #3	0	0.0	1	0.2	0	0.0
Hydropsychidae						
Hydropsyche philo Ross	0	0.0	0	0.0	2	0.6
Hydropsyche occidentalis Banks	11	7.6	3	0.6	1	0.3
Hydropsyche oslari Banks	12	8.3	21	4.4	10	2.9
Parapsyche almota Ross	0	0.0	2	0.4	3	0.9
Rhyacophilidae						
Rhyacophila narvae Navas	0	0.0	3	0.6	2	0.6
Rhyacophila pellisa Ross	0	0.0	35	7.3	22	6.4
Rhyacophila sierra Denning	0	0.0	0	0.0	1	0.3
Rhyacophila vao Milne	2	1.4	13	2.7	2	0.6
Rhyacophila vedra Milne	0	0.0	5	1.0	0	0.0
Rhyacophila vocala Milne	0	0.0	1	0.2	1	0.3
Rhyacophila undescr. sp. A	0	0.0	1	0.2	1	0.3
Rhyacophila undescr. sp. C	0	0.0	1	0.2	0	0.0
Unassociated *Rhyacophila* Females:						
Rhyacophila sp. #2	0	0.0	1	0.2	0	0.0
Rhyacophila sp. #5	0	0.0	3	0.6	10	2.9
Rhyacophila sp. #6	0	0.0	35	7.3	27	7.9
Rhyacophila sp. #7	0	0.0	4	0.8	6	1.7
Rhyacophila sp. #8	0	0.0	0	0.0	1	0.3
Rhyacophila sp. #9	0	0.0	6	1.3	0	0.0
Rhyacophila sp. #10	3	2.1	2	0.4	0	0.0

Table 2. *continued*

	1979 No.	1979 Percent of total	1980 No.	1980 Percent of total	1981 No.	1981 Percent of total
Glossosomatidae						
Agapetus taho Ross	23	16.0	0	0.0	7	2.0
Unassociated *Agapetus*						
Female:						
Agapetus sp. #1	0	0.0	3	0.6	1	0.3
Anagapetus sp. A	1	0.7	2	0.4	0	0.0
Glossosoma oregonense Ling	0	0.0	1	0.2	0	0.0
Unassociated *Glossosoma*						
Female						
Glossosoma sp. #1	0	0.0	8	1.7	4	1.2
Hydroptilidae						
Hydroptila arctia Ross	9	6.3	14	2.9	15	4.4
Hydroptila sp. A nr. *rono* Ross	12	8.3	1	0.2	3	0.9
Unassociated *Hydroptila*						
Females:						
Hydroptila sp. #1	8	5.6	9	1.9	5	1.5
Hydroptila sp. #2	0	0.0	1	0.2	1	0.3
Neotrichia sp. A	5	3.5	1	0.2	0	0.0
Unassociated *Neotrichia*						
Female:						
Neotrichia sp. #1	5	3.5	0	0.0	0	0.0
Ochrotrichia undescr. sp. A	1	0.7	0	0.0	0	0.0
Ochrotrichia undescr. sp. E	1	0.7	0	0.0	0	0.0
Ochrotrichia undescr. sp. F	0	0.0	0	0.0	2	0.6
Unassociated *Ochrotrichia*						
Female:						
Ochrotrichia sp. #1	1	0.7	3	0.6	1	0.3
Oxyethira sp. A	0	0.0	0	0.0	1	0.3
Unassociated Hydroptilidae						
Females:						
Hydroptilidae sp. #1	1	0.7	0	0.0	1	0.3
Brachycentridae						
Amiocentrus aspilus (Ross)	0	0.0	9	3.0	13	3.8
Unassociated *Amiocentrus*						
Females:						
Amiocentrus sp. #1	0	0.0	95	20.1	54	15.7
Amiocentrus sp. #2	0	0.0	0	0.0	1	0.3
Amiocentrus sp. #3	0	0.0	0	0.0	8	2.3
Micrasema undescr. sp. A	0	0.0	123	25.8	38	11.1

Table 2. *continued*

	No. (1979)	Percent of total (1979)	No. (1980)	Percent of total (1980)	No. (1981)	Percent of total (1981)
Lepidostomatidae						
Lepidostoma cantha Ross	0	0.0	36	7.5	67	19.5
Lepidostoma fischeri Denning	0	0.0	0	0.0	2	0.6
Lepidostoma strophis Ross	0	0.0	0	0.0	1	0.3
Unassociated *Lepidostoma* Females:						
Lepidostoma sp. #1	0	0.0	0	0.0	5	1.5
Lepidostoma sp. #2	0	0.0	0	0.0	1	0.3
Limnephilidae						
Limnephilidae sp. A	0	0.0	1	0.2	0	0.0
Sericostomatidae						
Gumaga nigricula (McL.)	1	0.7	2	0.4	2	0.6
Odontoceridae						
Marilia flexuosa Ulmer	2	1.4	16	3.4	14	4.1
Nerophilus californicus (Hagen)	0	0.0	1	0.2	0	0.0
Parthina vierra Denning	1	0.7	0	0.0	0	0.0
Helicopsychidae						
Helicopsyche borealis (Hagen)	17	11.8	2	0.4	1	0.3
Calamoceratidae						
Heteroplectron californicum McL.	1	0.7	2	0.4	2	0.6
Leptoceridae						
Mystacides alafimbriata Hill-Griffin	0	0.0	1	0.2	0	0.0
Oecetis sp. A	2	1.4	1	0.2	0	0.0
Total N	144		477		343	
Total No. Taxa (Excluding Unassociated Females)	18		30		27	
No. Unassociated Females	18		173		126	

wet year are compared. This statistic also allows the Trichoptera fauna at Big Sulphur Creek and Big Canyon Creek to be compared with other faunas. The 1979–1980 and 1980–1981 values of 0.104 and 0.098, respectively (each comparing a dry with an average year), are within the range of AV values for 14 temperate and tropical sites reported by McElravy et al. (1982) for Trichoptera; a comparison between the two dry years (1979 and 1981 AV = 0.063), however, is lower than any previously reported value.

Table 3. Comparison of Seasonal Range (SR) frequency distributions between Big Sulphur Creek (BSC) and Big Canyon Creek (BCC), and with four sites in North America having a continental temperate climate. Number of species for which SR was calculated is given below each site. Temperature data from the National Oceanic and Atmospheric Administration.

Site	Location	Elevation (m)	Latitude N	Mean Temp. (Oct.–April) °C	SR with BSC	SR with BCC
Big Sulphur Creek (N = 24)	N. Calif.	680	38° 46′	12.2	—	p = 0.49
Big Canyon Creek (N = 15)	N. Calif.	570	38° 51′	9.3	p = 0.49	—
Mahoning R. St. #2 (N = 33)	N.E. Ohio	347	41° 12′	2.9	p = 0.01	p = 0.02
Mahoning R. St. #3 (N = 30)	N.E. Ohio	326	41° 14′	2.9	p = 0.05	p = 0.16
Linesville Creek (N = 50)	N.W. Pa.	317	41° 40′	1.9	p = 0.01	p = 0.01
Fourmile Creek (N = 59)	N.W. Pa.	259	42° 7′	2.2	p < 0.01	p = 0.01

Table 4. Annual Variability (AV) of caddisfly faunas of Big Sulphur Creek and Big Canyon Creek as indicated by the mean and variance of the net reproductive rate (*sensu* Wolda, 1978). Calculations based on species for which the total number in both years ≥ 10.

Site	Years Compared	DF	Mean	Variance (= AV)
Big Sulphur Creek	1979–1980	7	−0.35	0.104
Big Sulphur Creek	1980–1981	7	0.09	0.098
Big Sulphur Creek	1979–1981	7	−0.29	0.063
Big Canyon Creek	1980–1981	8	0.36	0.373

The 1980–1981 AV for Big Canyon Creek, 0.373, is higher than that of Big Sulphur Creek for the same year. This value is exceptionally high for Trichoptera. In fact it is exceeded only by an AV of 0.925 that was reported for a Kentucky stream (Haag et al., 1984), in a study that compared pre-impact 1973 and impact 1979 faunas at a single site affected by siltation. Since we have only one set of comparative of data (from a dry to average pair of years) we do not know if AVs are generally higher in Big Canyon Creek than in Big Sulphur Creek. The benthic (immature) stages of the Trichoptera at both Big Sulphur Creek and Big Canyon Creek respond to year-to-year differences in precipitation (Resh et al., 1981; McElravy et al., unpublished data). In all probability, changes in numerical abundance of adult Trichoptera also result from the same conditions that affect the benthic stages of these species.

Faunal studies, in addition to providing descriptive accounts of insect populations and communities, are often done to make spatial (e.g., temperate/tropic; upstream/downstream) or temporal (e.g., changes in populations and communities following perturbation) comparisons. Wolda (1979) has emphasized that quantifying fluctuations in abundances is important in understanding the ecology of insect populations and communities. Quantitative indices such as Seasonal Range and Annual Variability may be used to summarize faunal information and permit statistical tests of temporal parameters among different data sets. The separation of seasonal or annual variability from variability produced by perturbation is a major concern in aquatic biology. If sampling programs for faunal studies can be designed and data reported in such a way that seasonality and/or annual variability measures can be applied, the value of such studies to researchers interested in partitioning this variability can be greatly enhanced.

Acknowledgments

We wish to thank John Wood for his assistance in the collection and sorting of samples, Mrs. Carol Hills for use of the Boggs Intermountain Coast Range Reserve property at Big Canyon Creek, and Dr. Donald Denning, Moraga, California, for confirming identifications. The research leading to this report was supported in part by the United States Department of the Interior, under the Matching Grant Program of Public Law 95–467, Project No. B-200-CAL, and the University of California Water Resources Center, Project UCAL-WRC-519.

Literature Cited

Brown, W. M. III, and L. E. Jackson, Jr. 1974. Sediment source and deposition sites and erosional and depositional provinces, Marin and Sonoma counties, California. U.S. Geol. Surv. Publ. No. MF-625, 32 pp.

Butler, M. G. 1984. Life histories of aquatic insects. Pp. 24–55. In: V. H. Resh and D. M. Rosenberg (eds.), The ecology of aquatic insects. Praeger Publishers, New York, 625 pp.

Gilman, C. S. 1964. Rainfall. Pp. 9–1—9–68. In: V. T. Chow (ed.), Handbook of applied hydrology. McGraw-Hill, New York.

Haag, K. H., V. H. Resh, and S. E. Neff. 1984. Changes in the adult caddisfly (Trichoptera) community of the Salt River, Kentucky. Trans. Ky. Acad. Sci., 45:101–108.

Hynes, H. B. N. 1970. The ecology of running waters. University of Toronto Press, Toronto, 555 pp.

Klopfer, P. H. 1959. Environmental determinants of faunal diversity. Amer. Nat., 93:337–342.

Lamberti, G. A. 1983. Interactions among benthic insects, algae, and bacteria in a geothermally influenced stream. Ph.D. thesis, University of California, Berkeley, California, 291 pp.

Lamberti, G. A., and V. H. Resh. 1983. Geothermal effects on stream benthos: separate influences of thermal and chemical components on periphyton and macroinvertebrates. Can. J. Fish. Aquat. Sci., 40:1995–2009.

MacArthur, R. H. 1972. Geographical ecology. Harper and Row, New York, 269 pp.

McColl, J. G., L. M. Gallagher, and C. P. Martz. 1978. Geochemical origin of surface waters in a geothermal area. Pp. 365–382. In: D. C. Adriano and I. L. Brisbin, Jr. (eds.), Environmental chemistry and cycling processes. U.S. Dept. Energy, Technical Information Center, Washington, D.C.

McElravy, E. P., V. H. Resh, H. Wolda, and O. S. Flint, Jr. 1981. Diversity of adult Trichoptera in a "non-seasonal" tropical environment. Proc. 3rd Int. Symp. Trichoptera, Ser. Entomol., 20:149–156.

McElravy, E. P., H. Wolda, and V. H. Resh. 1982. Seasonality and annual variability of caddisfly adults (Trichoptera) in a "non-seasonal" tropical environment. Arch. Hydrobiol., 94:302–317.

McMillan, L. E. (ed.). 1985. Geysers-Calistoga KGRA-ARM program 1982–1983 annual report. 2 vols.

Morse, J. C., J. W. Chapin, D. D. Herlong, and R. S. Harvey. 1980. Aquatic insects of Upper Three Runs Creek, Savannah River Plant, South Carolina. Part I: Orders other than Diptera. J. Georgia Ent. Soc., 15:73–101.

Neilson, D. 1975. Final environmental impact report for geothermal leasehold of Union Oil Co. at The Geysers, Sonoma County, California. Ecoview Environmental Consultants, Napa, CA.

Resh, V. H., K. H. Haag, and S. E. Neff. 1975. Community structure and diversity of caddisfly adults from the Salt River, Kentucky. Environ. Entomol., 4:241–253.

Resh, V. H., T. S. Flynn, G. A. Lamberti, E. P. McElravy, K. L. Sorg, and J. R. Wood. 1981. Responses of the sericostomatid caddisfly *Gumaga nigricula* (McL.) to environmental disruption. Proc. 3rd Int. Symp. Trichoptera, Ser. Entomol., 20:311–318.

Resh, V. H., G. A. Lamberti, E. P. McElravy, J. R. Wood, and J. W. Feminella. 1984a. Quantitative methods for evaluating the effects of geothermal energy development on stream benthic communities at The Geysers, California. California Water Resources Center Contr. No. 190, 57 pp.

Resh, V. H., G. A. Lamberti, and J. R. Wood. 1984b. Biology of the caddisfly *Helicopsyche borealis* (Hagen): A comparison of North American populations. Freshwater Invert. Biol., 3:172–180.

Sweeney, B. W. 1984. Factors influencing life-history patterns of aquatic insects. Pp. 56–100. In: V. H. Resh and D. M. Rosenberg (eds.), The ecology of aquatic insects. Praeger Publishers, New York, 625 pp.

Wolda, H. 1977. Fluctuations in abundance of some Homoptera in a neotropical forest. Geo-Eco-Trop., 3:229–257.

Wolda, H. 1978. Fluctuations in abundance of tropical insects. Amer. Nat., 112:1017–1045.

Wolda, H. 1979. Seasonality parameters for insect populations. Res. Popul. Ecol., 20:247–256.

Wolda, H. 1980a. Seasonality of tropical insects. I. Leafhoppers (Homoptera) in Las Cumbres, Panama. J. Anim. Ecol., 49:277–290.

Wolda, H. 1980b. Fluctuationes estacionales de insectos en el tropico: Sphingidae. Mem. VI Congr. Soc. Colombiana Entomol. (1979, Cali, Colombia), pp. 11–58.

Wolda, H., and F. W. Fisk. 1981. Seasonality of tropical insects. II. Blattaria in Panama. J. Anim. Ecol., 50:827–838.